



## Technology Focus: Sensors

### Collaborative Clustering for Sensor Networks

This technique can be used in sensor networks such as those for volcano and earthquake monitoring, intruder detection, target tracking, and data mining in cell phone networks.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Traditionally, nodes in a sensor network simply collect data and then pass it on to a centralized node that archives, distributes, and possibly analyzes the data. However, analysis at the individual nodes could enable faster detection of anomalies or other interesting events, as well as faster responses such as sending out alerts or increasing the data collection rate. There is an additional opportunity for increased performance if individual nodes can communicate directly with their neighbors.

Previously, a method was developed by which machine learning classification algorithms could collaborate to achieve high performance autonomously (without requiring human intervention). This method worked for supervised learning algorithms, in which labeled data is used to train models. The learners collaborated by exchanging labels describing the data. The new advance enables clustering algorithms, which do not use labeled data, to also collaborate. This is achieved by defining a new language for collaboration that uses pair-wise constraints to en-

code useful information for other learners. These constraints specify that two items must, or cannot, be placed into the same cluster. Previous work has shown that clustering with these constraints (in isolation) already improves performance.

In the problem formulation, each learner resides at a different node in the sensor network and makes observations (collects data) independently of the other learners. Each learner clusters its data and then selects a pair of items about which it is uncertain and uses them to query its neighbors. The resulting feedback (a "must" and "cannot" constraint from each neighbor) is combined by the learner into a consensus constraint, and it then re-clusters its data while incorporating the new constraint. A strategy was also proposed for "cleaning" the resulting constraint sets, which may contain conflicting constraints; this improves performance significantly. This approach has been applied to collaborative clustering of seismic and infrasonic data collected by the Mount Erebus Volcano Observatory in Antarctica.

Previous approaches to distributed clustering cannot readily be applied in a sensor network setting, because they assume that each node has the same "view" of the data set. A view is the set of features used to represent each object. When a single data set is partitioned across several computational nodes, distributed clustering works; all objects have the same view. But when the data is collected from different locations, using different sensors, a more flexible approach is needed. This approach instead operates in situations where the data collected at each node has a different view (e.g., seismic vs. infrasonic sensors), but they observe the same events. This enables them to exchange information about the likely cluster membership relations between objects, even if they do not use the same features to represent the objects.

*This work was done by Kiri L. Wagstaff of Caltech, Jillian Green of California State University of Los Angeles, and Terran Lane of University of New Mexico for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-47491*

### Teleoperated Marsupial Mobile Sensor Platform Pair for Telepresence Insertion Into Challenging Structures

**This configuration adds more flexibility to robotic rescue operations.**

*John H. Glenn Research Center, Cleveland, Ohio*

A platform has been developed for two or more vehicles with one or more residing within the other (a marsupial pair). This configuration consists of a large, versatile robot that is carrying a smaller, more specialized autonomous operating robot(s) and/or mobile repeaters for extended transmission. The larger vehicle, which is equipped with a ramp and/or a robotic arm, is used to operate over a more challenging topography than the smaller one(s) that may have a more limited inspection area to traverse. The intended use of this con-

cept is to facilitate the insertion of a small video camera and sensor platform into a difficult entry area. In a terrestrial application, this may be a bus or a subway car with narrow aisles or steep stairs.

The first field-tested configuration is a tracked vehicle bearing a rigid ramp of fixed length and width. A smaller six-wheeled vehicle approximately 10 in. (25 cm) wide by 12 in. (30 cm) long resides at the end of the ramp within the larger vehicle. The ramp extends from the larger vehicle and is tipped up into the air. Using video feedback from a

camera atop the larger robot, the operator at a remote location can steer the larger vehicle to the bus door. Once positioned at the door, the operator can switch video feedback to a camera at the end of the ramp to facilitate the mating of the end of the ramp to the top landing at the upper terminus of the steps. The ramp can be lowered by remote control until its end is in contact with the top landing. At the same time, the end of the ramp bearing the smaller vehicle is raised to minimize the angle of the slope the smaller vehicle has to climb, and fur-

ther gives the operator a better view of the entry to the bus from the smaller vehicle. Control is passed over to the smaller vehicle and, using video feedback from the camera, it is driven up the ramp, turned oblique into the bus, and then sent down the aisle for surveillance.

The demonstrated vehicle was used to scale the steps leading to the interior of a bus whose landing is 44 in. ( $\approx 1.1$  m) from the road surface. This vehicle can position the end of its ramp to a surface over 50 in. ( $\approx 1.3$  m) above ground level and can drive over rail heights exceeding

ing 6 in. ( $\approx 15$  cm). Thus configured, this vehicle can conceivably deliver the smaller robot to the end platform of New York City subway cars from between the rails. This innovation is scalable to other formulations for size, mobility, and surveillance functions. Conceivably the larger vehicle can be configured to traverse unstable rubble and debris to transport a smaller search and rescue vehicle as close as possible to the scene of a disaster such as a collapsed building. The smaller vehicle, tethered or otherwise, and capable of penetrating and tra-

versing within the confined spaces in the collapsed structure, can transport imaging and other sensors to look for victims or other targets.

*This work was done by Michael J. Krasowski, Norman F. Prokop, and Lawrence C. Greer of Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18673-1.*

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## Automated Verification of Spatial Resolution in Remotely Sensed Imagery

**Automated tool assesses image spatial resolution without the need for dedicated edge targets.**

*Stennis Space Center, Mississippi*

Image spatial resolution characteristics can vary widely among sources. In the case of aerial-based imaging systems, the image spatial resolution characteristics can even vary between acquisitions. In these systems, aircraft altitude, speed, and sensor look angle all affect image spatial resolution. Image spatial resolution needs to be verified with estimators that include the ground sample distance (GSD), the modulation transfer function (MTF), and the relative edge response (RER), all of which are key components of image quality, along with signal-to-noise ratio (SNR) and dynamic range. Knowledge of spatial resolution parameters is important to determine if features of interest are distinguishable in imagery or associated products, and to develop image restoration algorithms.

An automated Spatial Resolution Verification Tool (SRVT) was developed to rapidly determine the spatial resolution characteristics of remotely sensed aerial and satellite imagery. Most current methods for assessing spatial resolution characteristics of imagery rely on pre-de-

ployed engineered targets and are performed only at selected times within pre-selected scenes. The SRVT addresses these insufficiencies by finding uniform, high-contrast edges from urban scenes and then using these edges to determine standard estimators of spatial resolution, such as the MTF and the RER.

The SRVT was developed using the MATLAB® programming language and environment. This automated software algorithm assesses every image in an acquired data set, using edges found within each image, and in many cases eliminating the need for dedicated edge targets. The SRVT automatically identifies high-contrast, uniform edges and calculates the MTF and RER of each image, and when possible, within sections of an image, so that the variation of spatial resolution characteristics across the image can be analyzed. The automated algorithm is capable of quickly verifying the spatial resolution quality of all images within a data set, enabling the appropriate use of those images in a number of applications.

The SRVT has been validated against traditional techniques using IKONOS and QuickBird satellite imagery of NASA Stennis Space Center engineered edge targets. Preliminary comparisons of SRVT-estimated spatial resolution from naturally occurring edges against those obtained using traditional techniques show excellent agreement.

The SRVT can be used to evaluate the image quality of a single image, a product over time, and products from different systems. In addition to the above image quality metrics, the output of the SRVT could be used to estimate National Imagery Interpretability Rating Scale (NIIRS) values for panchromatic imagery, and serve as the basis for developing multispectral image-quality metrics.

*This work was done by Bruce Davis of Stennis Space Center, Robert Ryan and Kara Holekamp of Science Systems and Applications, Inc., and Ronald Vaughn of Computer Sciences Corporation. For more information Contact the Office of the Chief Technologist at Stennis Space Center, (228) 688-1929. Refer to SSC-00339.*

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## Electrical Connector Mechanical Seating Sensor

*John F. Kennedy Space Center, Florida*

A sensor provides a measurement of the degree of seating of an electrical connector. This sensor provides a number of discrete distances that a plug is inserted into a socket or receptacle. The

number of measurements is equal to the number of pins available in the connector for sensing.

On at least two occasions, the Shuttle Program has suffered serious time delays

and incurred excessive costs simply because a plug was not seated well within a receptacle. Two methods were designed to address this problem: (1) the resistive pin technique and (2) the discrete